REMARKS/ARGUMENTS

The amendment to Claim1 provides explicit antecedent basis for the term "molten sulfur" and generally clarifies the claim. The amendments to Claims 2, 3 and 8 similarly clarify these claims.

The amendment to Claim 9, indicated as allowable, places this claim in independent form. Newly added Claims 13-16 repeat Claims 2-4 and 8, but depend from allowable Claim 9. Thus, Claims 9-16 are in condition for issuance. The Examiner is thanked for this indication of allowable subject matter.

Finally, new Claims 17-20 find support in the paragraph bridging pages 4 and 5 of the specification. No new matter has been entered.

The present invention relates to a new process for the disposal of sulfur, for example sulfur coming from the purification treatment of crude oil and natural gas. In the invention process sulfur is melted to provide molten sulfur and the molten sulfur is injected into a geological structure having a temperature ranging from 90 to 160°C. This temperature range, 90 to 160°C, is important because below 90°C sulfur solidifies while at temperatures higher than 160°C sulfur becomes very viscous, and cannot be pumped. See, for example, the attached excerpt from the Encyclopedia of Chemical Technology. An important benefit of the present invention is that the disclosed sulfur can be injected into the same geological structure from which the crude oil and natural gas originated, including matrix geological structures which are porous, and naturally or induced fractured structures. See the paragraph bridging pages 4 and 5 of the present specification and new Claims 17-20.

Pickren relates to an underground storage method for sulfur where liquid sulfur can be injected through a borehole and into a cavity. See the paragraphs bridging columns 3 and 4 of the reference. However, the underground cavity into which the sulfur is injected is at a

temperature below the melting point of sulfur. See column 4, lines 31-40 of Pickren.[1] Notably, the cavity in Pickren is one in a salt bed or salt dome, which should not contain any fractures or have porosity and should be located about 3,000 feet below the earth's surface. See column 3, lines 31-38 and 55-57 of the reference.

Jacoby relates to the extraction of geothermal heat from the earth's core. This can be done by locating a cavern deep in a salt deposit and pumping air through it. As noted at column 4, lines 60ff of Jacoby, the cavern should be located at least 20,000 feet below the earth's surface, and preferably deeper. At these levels the temperature of the earth is generally over 350°F (176°C) in order to maintain the temperature of the air moving through the cavern above 200°F.

Applicants respectfully submit that one of ordinary skill in the art would not move the Pickren cavity, located in a salt bed/dome, down 17,000 feet in view of Jacoby. What would be the reason? Even if one were to do this, the temperature of the surrounding salt would be above the presently claimed range.

There is simply no motivation to move the Pickren cavity. Certainly, Jacoby does not provide such motivation. In this regard, no reference of record, including Bailey, discloses or suggests the use of a geological structure having a temperature ranging from 90 to 160°C, and certainly no reference discloses or suggests the several benefits that such structures provide, as shown herein.

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[1] Here, the reference explains that if a pool of molten sulfur is to be maintained in the cavity heat must be supplied ("For long-term storage, i.e., 5 to 10 years, and longer, the pool is allowed to freeze by discontinuing heat input.") (emphasis added)).

Accordingly, and in view of the above amendments and remarks, Applicants respectfully submit that the present application is in condition for allowance, and early notification to this effect is respectfully requested.

Respectfully submitted,

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sulfide in natural gas; organic compounds in petroleum and tar sands; and a combination of both pyritic and organic compounds in coal.

Properties

Allotropy. Sulfur occurs in a number of different allotropic modifications, that is, in various molecular aggregations which differ in solubility, specific gravity, crystalline form, etc. Like many other substances, sulfur also exhibits dynamic allotropy, ie, the various allotropes exist together in equilibrium in definite proportions, depending on the temperature and pressure. The formulas for the molecules of various allotropes is $S–S_n$, where n is a very large but unidentified number, ie, $n > 10^6$. The particular allotropes that may be present in a given sample of sulfur depend to a large extent upon its previous thermal history, the amount and type of foreign substance present, and the length of time that has passed for equilibrium to be attained.

In the solid and liquid states, the principal allotropes are designated traditionally as $S\lambda$, $S\mu$, and $S\pi$. Of these, only $S\lambda$ is stable in the solid state. Upon solidification of molten sulfur, $S\pi$ rapidly changes into $S\mu$, which is converted into $S\lambda$ although at a much slower rate. The molecular structure of $S\pi$ is that of an octatomic sulfur chain (1–2). The symbol $S\mu$ designates long, polymerized chains of elemental sulfur. $S\lambda$ is perhaps the most characteristic molecular form of sulfur, namely, that of a crown-shaped, octatomic sulfur ring designated in more recent literature as S_8^8 (3). The allotropes differ in their solubility in carbon disulfide. $S\pi$ and $S\lambda$ are soluble in carbon disulfide, whereas $S\mu$ does not dissolve in this solvent.

Sulfur crystallizes in at least two distinct systems: the rhombic and monoclinic forms. Rhombic sulfur, $S\alpha$, is stable at atmospheric pressures up to 95.5°C, at which transition to monoclinic sulfur, $S\beta$, takes place. Monoclinic sulfur is then stable up to its natural melting point of 114.5°C. The basic molecular unit of both of these crystalline forms of sulfur is the octatomic sulfur ring S_8^8. Other forms of solid sulfur include hexatomic sulfur, as well as numerous modifications of catenapolysulfur (2,4).

The molecular constitution of liquid sulfur undergoes significant and reversible changes with temperature variations. These changes are evidenced by the characteristic temperature dependence of the physical properties of sulfur. In most studies of liquid sulfur, some striking changes in its physical properties are observed at ca 160°C. For example, the viscosity of purified sulfur at 120°C is about 11 mPa·s (= cP) drops to a minimum of 6.7 mPa·s at ca 157°C, and then begins to rise. At 159–160°C, the viscosity of liquid sulfur rises very sharply increasing to 30 mPa·s at 160°C and reaches a maximum of ca 93 Pa·s (930 P) at 187°C. Above this temperature, the viscosity gradually drops off again to ca 2 Pa·s (20 P) at 306°C. A qualitative exploration of these viscosity changes in terms of the allotropy of sulfur implies that, below 159°C, sulfur consists mainly of S_8 rings, and a normal decrease of viscosity with rising temperature is observed. The sudden increase in the viscosity of sulfur above 159°C is attributed to the formation of polymeric sulfur chain molecules. Then, as the temperature rises further, the concentration of polymeric sulfur continues to increase, but the opposing effect of decreasing chain length resulting from thermal sulfur–sulfur bond scission causes a gradual decrease in viscosity in the temperature range between 187°C and the boiling point of sulfur. The chemical equilibria between the various forms in molten